OPEN WIRE CIRCUIT PROTECTION

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1. GENERAL

1.1 This section is intended to provide REA borrowers, consulting engineers, contractors and other interested parties with technical information for use in the design and construction of REA financed telephone systems. It discusses electrical protection measures and protection devices which are applied to open wire telephone circuits. Because open wire circuits have a dielectric strength much higher than other types of facilities to which they are connected, protection applied to open wire facilities consists of means to protect persons and property from the effects of electric supply circuits in proximity to the open wire circuits and to protect connected facilities of lower dielectric strength against damaging lightning surges which can be fed from the open wire to the lower dielectric strength facilities. The protection of poles against lightning is also included in this section for convenience. The basic principles of protection of telephone plant are included in TE & CM-801, "Conditions Requiring Electrical Protection." Familiarity with these principles is necessary for understanding the specific information provided in this section.

1.2 This section replaces TE & CM-820, Issue No. 2, dated June 1957. The principal changes include the provision of more complete requirements to ensure better coordination of power and telephone systems with the intent of safeguarding both maintenance personnel and the public from the standpoint of personal safety.

1.3 Coordination of power and communication circuits is not required where Grade B construction (See National Electrical Safety Code) exists. However, provision of Grade B construction is more expensive than coordination in accordance with this section, and is not, therefore, recommended.

2. POWER CONTACT PROTECTORS

2.1 Power contact protectors serve as means of achieving coordinated electrical protection of open wire telephone circuits which are exposed to the possibility of contact with electric supply circuits. They have two functions in the event of a contact between power and telephone conductors:

a. To achieve prompt deenergization of the power circuit, and

b. to prevent holdover of subscribers' station protector fuses.

Coordinated electrical protection exists (1) when the power and telephone circuits are so constructed, operated, and maintained that the power circuit will be deenergized promptly, both initially and on subsequent operations of power protective equipment, in the event of a contact with telephone plant, and (2) when the voltages and currents impressed on the telephone plant during the period before the power circuit is deenergized are limited so as to avoid fire hazard to telephone stations, and shock hazard to personnel who may come into contact with the telephone line.

2.2 Power contact protectors consist of air gap arresters with carbon electrodes, connected between each of the telephone conductors and ground. These arresters break down at approximately 2000 volts rms. Typical current carrying capability of these protectors is shown on Figure 1.

2.3 If the time-current characteristic of the power line protective devices falls to the left of the curve in Figure 1, and to the left of the time-current fusing characteristic of the telephone conductor, (Figure 3), this means that the power system will be deenergized before the power contact protector is destroyed and before the line wire is fused, and coordination is assured. If the power circuit breaker curve falls to the right of the curve in Figure 1, it means that the power contact protector will be destroyed before the power breakers permanently deenergize the power circuit. If the power circuit breaker curve falls to the right of the time current fusing curve for the telephone conductor, it means that the telephone wire will fuse open before the power line is permanently deenergized, with the likelihood that the telephone conductor will remain energized indefinitely. All types of line wire found in REA plant (except for 104 copper) will have a more sensitive fusing characteristic than the power contact protector so that if the power system breaker characteristic falls to the left of the line wire curve, coordination with the power contact protector is automatically assured. Appendix A gives illustrative examples.

2.4 Because the power fault current decreases with time due to increase in resistance of the line wire, this fact must be taken into account in determining whether coordination exists. Figure 2 shows the relationship between time and the ratio of hot to cold resistance for 109-135 steel telephone wire. From these curves, the time required for fusing 109-135 wire at constant currents may be derived. (Figure 3)

2.5 Power contact protectors are used to provide a low impedance path to ground for electric supply fault currents in the event of a power contact, and a further function of these protectors is to reduce the duty on subscriber station protectors to safe values; therefore, it is evident that in their application the lowest resistance ground connection practicable should be used for proper operation. This condition can usually be obtained if the ground leads of the power contact protectors are connected to the multigrounded neutral (MGN) of an electric supply system.

2.6 With other than MGN type electric distribution systems, coordination is usually more difficult and may be impracticable to achieve because of the absence of a low impedance path to ground for power contact protectors. Unigrounded neutral systems and delta systems equipped with grounding banks and ground relaying have permanent ground connections at substations. The ability to achieve coordinated protection with such systems in the event of a contact with a telephone circuit is, therefore, largely dependent upon the availability of sufficiently low resistance local ground electrodes for grounding power contact protectors. The maximum permissible ground resistance can be computed for each protector location. With isolated delta power systems having no ground connection at substations, large fault currents will flow in a telephone circuit in the event of a contact only under rather special conditions. The probability of these conditions occurring cannot be accurately predicted. Deenergization of isolated delta power systems cannot be controlled by the spacing nor the ground resistance of power contact protectors on the telephone system. It is, therefore, considered impracticable to achieve coordinated electrical protection with an isolated delta power system and power contact protectors should not be installed. Where such power systems are involved, special care should be taken to avoid conflicts between the power and telephone systems and if joint use is contemplated, Grade B construction should be required.

2.7 Before specifying power contact protectors in a telephone system which is exposed to the possibility of contacts with an electric distribution system, other than an isolated delta power system, the borrower's engineer should investigate the time-current characteristics of the fuses, circuit breakers, and other protective devices installed on

the electric supply system and compare them with the time-current characteristics of the power contact protectors and with the time-current fusing characteristic of the line wire involved, to determine if coordinated electrical protection can be achieved. Figures 1, 2, and 3 may be used as a rough check to determine if coordination can readily be achieved with normal spacing on 109-135 steel line wire. If coordination does not appear possible with the standard spacing, closer spacing of protectors should be considered. Appendix B provides an example of system analysis for a typical case.

2.8 With typical rural electric distribution systems of the MGN type whose maximum fault currents do not exceed about 1500 amperes and whose nominal voltage to ground is between 3000 and 15,000 volts, there is usually no problem in obtaining coordinated protection if power contact protectors are grounded to the MGN and are spaced at proper intervals.

2.81 Normally the spacings indicated in subsection 3 will prevent holdover of station fuses, but analysis in accordance with Appendix A is desirable to ensure that the recommended spacing is acceptable in specific cases, from the standpoint of holdover.

3. INSTALLATION OF POWER CONTACT PROTECTORS

3.1 General conditions where power contact protectors are required.

3.11 Power contact protectors should be installed on open wire telephone circuits where there are possibilities of contact with electric supply circuits with which coordination is practicable. The possibility of contact will generally exist at (1) poles which are in joint use, (2) conflicts, and (3) crossings. Power contact protectors should be used where multigrounded neutral power systems operating between 3000 and 15,000 volts to ground are involved. For multigrounded neutral supply systems whose operating voltages are outside the above limits, and for other types of electric supply systems which are involved in possible contacts, a special study is required by the engineer.

3.2 Standard joint use installation

3.21 The standard installation of power contact protection on open wire telephone circuits carried on poles which also carry multigrounded neutral electric supply circuits is as follows:

3.211 Install standard/1 power contact protectors on all open wire circuits on the top crossarm of the telephone lead at the poles where joint use begins and ends.

/1 "Standard" power contact protectors are those having a nominal breakdown value of 2000 volts rms, a time-current curve equal to or better than Figure 1, and listing in the "List of Materials Acceptable for Use on Telephone Systems of REA Borrowers."

3.212 Install additional power contact protectors at intervals as determined by analyses as illustrated in Appendices A and B. These spacings will usually be at intervals of about 20 ohms per single line conductor. Table I gives information on distances which approximate 20 ohms for various conductors.

3.213 Ground protectors to the multigrounded neutral via a vertical pole ground wire in accordance with 3.23.

TABLE I

Type of Conductor	Interval in miles between power contact protectors for joint use	Interval in miles from crossing equipped with power contact protectors
104 copper	4.0	2.0
080 40% copper-covered steel	1.0	0.5
104 40% " " "	2.0	1.0
128 40% " " "	3.0	1.5
080 30% " " "	0.7	0.35
104 30% " " "	1.0	0.5
128 30% " " "	2.0	1.0
091 Aluminum-clad steel	0.6	0.3
102 " " "	0.8	0.4
128 " " "	1.0	0.5
109 Galvanized steel Grade 85	0.5	0.25
109 " " " 135	0.5	0.25
109 " " " 190	0.5	0.25
134 " " " 135	0.8	0.4

3.22 The standard installation should be specified in all instances where its use will result in meeting the requirements for coordinated protection. Installations which do not comply with 3.21 are regarded as special installations. Special installations should be specified only where the special study referred to in 3.11 shows the need.

3.23 Connection of the ground leads of power contact protectors to the MGN of the power line should be accomplished by the appropriate method for the conditions prevailing at the pole in question as follows:

3.231

Condition	Method
Pole already equipped with a vertical pole ground wire which is connected to the MGN	The ground leads of the power contact protectors should be connected to the vertical pole ground wire by telephone linemen if this has been agreed to by the power company.

3.232

Condition	Method
Pole not equipped with vertical pole ground wire	If the pole in question is at the beginning or end of a joint use section, a #10 copper ground wire should be attached to the pole one foot below the telephone wire support fixture and should be extended up the pole just through the telephone working space. A sufficient length of the #10 copper ground wire to reach and be connected to the MGN should be left coiled and taped. The ground leads of the power contact protectors should be connected to the #10 ground wire. The connection of the #10 ground wire to the MGN should be made only by a power company lineman. If the pole in question is not at the beginning nor at the ending of a joint use section, the location of the protector may be shifted one span in either direction in order to make the installation on a pole which is already equipped with a vertical pole ground wire.

3.3 Limited Joint Use Sections

3.31 There are situations (Figure 4) where telephone and power circuits are carried on separate pole lines except for short joint use spurs running from the main pole lines to a subscriber's residence. Where such situations occur (and coordinated protection is practicable with the standard installation) one power contact protector per circuit should be installed on the telephone circuits at the location where the joint use begins. The installation of only one power contact protector per circuit is adequate for this type of joint use if the resistance of one conductor of the joint use spur from the point of crossing to its end does not exceed 10 ohms. The requirements given in 3.231 and 3.232 apply also on installations of this type.

3.4 Crossings

3.41 Joint pole crossings with multigrounded neutral type electric supply circuits - 3-15 kV to ground

3.411 Crossings of electric supply circuits and telephone circuits should be made on joint poles where practicable, as pointed out in REA TE & CM-801. With proper attention given to the mechanical design of a jointly used pole at a crossing, and with power contact protectors installed, the situation from a standpoint of the telephone plant is more favorable than at a crossing made on separate poles, since the possibility of contact is decreased and a good ground connection for the power contact protector is usually readily established.

3.412 Where a crossing of an electric supply circuit of the common multigrounded neutral type is made at a jointly used pole, power contact protectors should be installed at the crossing pole on the circuits occupying the top crossarm of multicircuit open wire leads or on the single circuit of single circuit leads, except as may be modified by 3.413.

3.413 Power contact protector installations at joint pole crossings with MGN type power lines provide a low impedance path to ground for fault currents on circuits exposed to power contacts for a distance on each side of the crossings. A circuit which is involved in more than one crossing with the same power line need not be provided with power contact protectors _if_ it has a power contact protector installed at an adjacent crossing within the intervals specified in Column 2 of Table I. The connection of the ground lead of power contact protectors to the MGN discussed in 3.231 and 3.232 applies also at crossings.

3.42 Joint pole crossings with electric supply circuits of other than the multigrounded neutral type, 3-15 kV to ground or between phases:

3.421 With electric systems of other than the multigrounded neutral type, it is more difficult to provide effective electrical protection. Construction at joint pole crossings, therefore, is even more important than with multigrounded neutral systems since greater reliance must be placed on avoiding contacts by interposing structural plant between the power and telephone conductors which minimizes the probability of contacts. Considerations which would govern whether or not power contact protectors should be installed at crossings with other than MGN type power systems are discussed below.

3.422 Power contact protectors should be specified at crossings with unigrounded "wye" and delta power circuits equipped with grounding banks and ground relaying if the special study discussed in REA TE & CM-801 indicates that coordinated electrical protection is practicable. The engineer should determine specifically: (1) The method of grounding power contact protectors, (2) the maximum permissible ground resistance, and (3) whether or not special protectors are needed.

3.423 Power contact protectors should not be installed at crossings with isolated delta type power systems.

3.43 Crossings with electric supply circuits in excess of 15 kV to ground.

3.431 The use of power contact protectors at a crossing will frequently make it unnecessary to adopt further precautions even if the nominal electric supply circuit line voltage is somewhat in excess of 15,000 volts to ground, provided coordination can be achieved. However, at crossings where the electric circuit voltage to ground is of the order of 25,000 volts or higher, joint pole crossings are not generally recommended and the borrower's engineer should determine what protection measures, if any, need be taken. This is the case whether the electric circuit is classified as a transmission circuit or as a distribution circuit. In general, the higher the voltage of the electric system the less the probability of a power contact due to the increased strength and clearances required for the electric system. This is particularly true for power transmission systems where the importance of a line from the power operating standpoint calls for a greater margin of strength in design and construction. Specifically, the engineer should check the general physical condition of the power line and its basic strength. If these two factors are satisfactory, specific measures of electrical protection at the crossings are usually unnecessary. If either of these factors is unsatisfactory, a cooperative design should be developed with the power organization to obtain a crossing of adequate mechanical strength and clearances. Alternatives to this would be to consider (1) an underground crossing or (2) a joint pole crossing with electrical protection if an investigation of the power system fault currents and protective device settings indicate there is any practical possibility of obtaining electrical coordination with either standard or special power contact protectors on the telephone line.

3.44 Inspan crossings with electrical supply circuits, 3-15 kV to ground or between phases.

3.441 No effective protection arrangements comparable to joint pole crossings are available for crossings within spans. Where such crossings cannot be avoided it will usually be necessary to rely on adequate construction at the crossing. As an alternative, it may be practicable to protect crossings within spans by means of power contact protector installations at a nearby point where a common multigrounded neutral is available. Other alternatives in cases of within-span crossings with multigrounded neutral supply circuits include the installation of power contact protectors on one side of the crossing and connection of the protector ground leads to the neutral by means of trenching or a slack span (Unit PM2B of REA Form 511) depending on local conditions. Another possible alternative which can be used with other types of supply systems,

except isolated delta systems, is to install power contact protectors on one side of the crossing, and ground them locally by means of a ground electrode, or electrodes, having a ground resistance low enough to insure coordination, if this can be achieved at a reasonable cost. In all cases coordination requires that the power system circuit breaker characteristics shall be such that the telephone line wire will not be fused open and the power contact protector will not be destroyed.

4. CABLE BUFFER PROTECTION

4.1 Air gap lightning arresters should be installed on open wire leads where required for cable "buffer" protection as outlined in REA TE & CM-815. Lightning arresters should not be installed on circuits on which power contact protectors are installed within one-half mile of the cable deadend as these protectors afford lightning protection as well as power contact protection.

5. DRAINAGE UNITS - THEORETICAL CONSIDERATIONS

5.1 As explained in REA TE & CM-801, open wire telephone circuits in joint use with, or in parallel construction with electric supply lines will have voltages induced in them by both the electric and the magnetic fields surrounding the power conductors. The voltages due to the magnetic field under load or fault conditions in most instances are not large enough to require mitigative measures. In situations involving unusually high fault currents and severe exposures, special protective measures may be required and are discussed in REA TE & CM-825. Drainage units discussed herein do not provide effective protection against magnetically induced voltages.

5.2 The magnitude of the electrically induced voltage on an unterminated open wire telephone conductor having infinite leakage resistance depends primarily on the relation:

$$V_T = V_P \frac{C_1}{C_1 + C_2} \quad \text{Where}$$

V_T = induced voltage to ground of the telephone conductor,
V_P = residual voltage (vector sum of the voltage in all wires to ground) of the power line,
C_1 = capacitance per unit length between the power conductors and the telephone conductors,
C_2 = capacitance per unit length between the telephone conductor and ground.

The degree of annoyance, or the extent of surprise shock to which a lineman could be subjected if he contacted the unterminated telephone conductor depends primarily on the current that could be passed through his body rather than on the voltage. For typical situations this current is roughly:

$I = V_p\, w\, C_1\, L$ where:
V_p = residual voltage of the power line
$w = 2\pi$ x frequency
C_1 = capacitance per unit length between the power conductors and the telephone conductor in farads
L = Length of the exposure

The magnitude of both the voltage and currents given by the above equations represent maximum values and would be reduced somewhat by the parallel paths from the telephone conductor to ground provided by divided ringers and leakage.

5.3 As indicated in REA TE & CM-801, the electrically induced voltage may be quite high on severely exposed lines and the current which could be drawn through a contact may be large enough to cause a hazardous surprise shock. A high electrically induced voltage level on a telephone line can also cause (1) dusting of carbon blocks, (2) false ringing of ringers, and (3) damage to ringers. These conditions can usually be offset by equipping the telephone line with drainage units. Drainage units of a suitable type should be installed in such quantities as needed to reduce the voltage on the line to about 50 volts and the current which can be drawn through a 1500-ohm ground at any point on the telephone line to approximately 0.016 amperes, where practicable to do so. From a practical consideration the current which would be drawn through a 1500-ohm resistor is due in part to the electrically induced voltage and in part to the magnetically induced voltage. In this discussion, as previously indicated, it has been assumed that the current due to magnetically induced voltage is negligible. In some instances, however, the current due to magnetic induction may to too large to ignore. All of the following installation instructions are based primarily on electrical protection considerations. Considerations regarding the effect of drainage units on noise are covered in REA TE & CM-451.

5.4 Since the residual voltage of 3-phase power distribution lines is unusually small, drainage units are not usually necessary on telephone lines which are in joint construction with or are located in close proximity to 3-phase power lines operating at voltages up to 15 kV. Similarly, for exposures to power lines of any type operating at voltages less than 6900 volts to ground, drainage units are not usually needed on telephone circuits if the exposure is less than 15 miles in length.

5.5 On multicircuit open wire telephone leads, a considerable amount of mutual shielding is provided between the several telephone conductors. The application of drainage units to one or two circuits on a multicircuit lead will substantially reduce the voltage induced on the undrained circuits as well as on the drained circuits. Advantage is taken of this fact in our installation instructions in the following paragraphs which limit the installation of drainage units to the top crossarm only in all cases, and to not more than two circuits on the top arm in the case of joint use with circuits of 8700 volts or less.

5.6 Drainage units of the inductor-capacitor type (Section 6.1) present a relatively low longitudinal impedance to ground for 50 to 70 Hz and a relatively high impedance across the line at voice frequencies. This provides effective drainage without appreciable transmission or ringing loss on systems using ringing frequencies of 30 Hz or lower. At frequencies within the range of 50 to 70 Hz, the impedance of tuned drainage units with one line terminal grounded, as is the case during ringing, is somewhat comparable to that of a fairly low impedance ringer. The shunting effect of two or more drainage units, to grounded ringers responding to selected frequencies within the range of 50 to 70 Hz, may be sufficient to prevent satisfactory ringing on long loops. Ringers in this frequency range, therefore, should be located as near to the central office as practicable and the use of 60 Hz ringers should be avoided where possible. Since the impedance of the ground connection of the drainage unit is in series with the longitudinal impedance of the unit, maximum drainage efficiency will be achieved when it is connected to a low impedance ground electrode. In most instances the lowest impedance ground electrode which is readily available is the MGN of the electric supply line. The gain in drainage efficiency resulting from grounding drainage units to an MGN in lieu of to a ground rod of 100- to 150-ohms resistance is not large and is offset to some extent by the probability that the units will be destroyed in the event of a power contact. However, it is important in some instances to keep the level of the induced voltages on the telephone line to a minimum to alleviate noise problems. Grounding drainage units to the MGN in all joint use applications is also less expensive construction than connecting to ground rods. In view of the above, drainage units installed on telephone circuits which are carried on joint use MGN electric poles should always be grounded to the MGN via a vertical pole ground wire.

5.7 At carrier frequencies the insertion loss of present standard inductor-capacitor drainage units is very small and may be neglected.

6. DRAINAGE UNITS - DESCRIPTION AND INSTALLATION

6.1 Drainage units consist usually of inductor-capacitor networks connected from each side of the line to ground. With the inductor-

capacitor type (Figure 5) an additional "tuning" inductor is connected from the center of the bridged networks to ground. Air gap protector blocks are normally used to protect such units from high potentials due to lightning or other causes.

6.2 <u>Open wire joint use with single or "vee" phase power circuits operating at 6900-8700 volts to ground.</u>

6.21 <u>Joint use sections less than 10 miles in length:</u>

6.211 Do <u>not</u> install drainage units as part of initial construction. Wait until system is in operation to determine if drainage units are necessary.

6.212 On multicircuit leads which require drainage, one drainage unit per circuit should be installed on each of the two circuits on the top crossarm, which are subject to the greatest exposure.

6.213 The drainage unit on each of the circuits selected should be located at approximately the mid-point of the joint use section.

6.214 The drainage units should be grounded to an MGN in accordance with 6.224.

6.22 <u>Joint use sections exceeding 10 miles in length:</u>

6.221 Install inductor-capacitor type drainage units equivalent to the Western Electric Company's No. 108C as part of the <u>initial construction</u>.

6.222 On multicircuit leads two drainage units per circuit should be installed on each of the two circuits on the top crossarm, which are subjected to the greatest exposure.

6.223 If the joint use section is "X" miles long (where "X" exceeds 14 miles and does not exceed about 25 miles) the first unit should be located at approximately X/4 miles from the beginning of the joint use section. The second unit on each of the two circuits should be located approximately 3X/4 miles from the beginning of joint use. If the joint use section is less than 14 miles, a single drainage unit should be installed at approximately the midpoint of the joint use section.

6.224 The ground terminals of the drainage units should be connected to an MGN via a vertical pole ground wire.

6.3 Open wire joint use with single or "vee" phase power circuits operating at 8700-15,000 volts to ground.

6.31 Joint use sections - zero to 10 miles in length

6.311 Install one inductor-capacitor type drainage unit equivalent to the Western Electric's No. 108C on each circuit on the top crossarm as part of the initial construction.

6.312 Locate the drainage units at approximately the midpoint of the joint use section and ground to the MGN as described in 6.324.

6.32 Joint use section exceeding 10 miles in length

6.321 Install inductor-capacitor type drainage units equivalent to the Western Electric Company's No. 108C, as part of the initial construction.

6.322 Two drainage units per circuit should be installed on each pair on the top crossarm.

6.323 If the joint use section is "X" miles long, (where "X" does not exceed about 20 miles), the first unit on each circuit should be located approximately X/4 miles from the beginning of the joint use section. The second unit on each circuit should be located approximately 3X/4 miles from the beginning of the joint use section. It is probable that if "X" exceeds about 15 miles on single circuit leads, or 20 miles on multicircuit leads, that two drainage units per circuit will not provide sufficient drainage. In such cases the procedure described in 6.5 should be followed.

6.324 The ground terminals of the drainage units should be connected to the multigrounded neutral of the power system via a vertical pole ground wire.

6.4 In all of the above instances requiring the installation of drainage units "as part of the initial construction" the drainage unit installations should be made and completely terminated before the ground connections required in 8.1 are removed. It is important that this procedure be followed to prevent possible dusting of carbon blocks and to eliminate shock hazard.

6.5 The limitation of two tuned drainage units per circuit may not always result in maintaining the induced voltage in the telephone circuits at a sufficiently low level to achieve the objectives stated in 5.3. This limitation is necessary in most instances, however, because of ringing difficulties which probably would be encountered if more than two drains per circuit were used. Whether or not ringing trouble would occur if more

than two drainage units were installed depends on many factors, including (1) the ringing generator voltages, frequencies, and regulation curves; (2) the ringers' impedances, sensitivities and selectivities; (3) the method of connecting ringers, (4) the loop resistance; and (5) the degree of balance of the line. If, after all terminations have been made, the voltage level with two drainage units is still high enough to dust carbons or cause bell tapping, a third unit should be connected midway between the other two. Ringing tests should then be made at all stations on the line to determine if satisfactory ringing can still be obtained.

6.6 Nonjoint Exposures

6.61 Open wire telephone leads which are exposed in other than joint use situations, such as at roadway separations, usually have much less voltage induced in them because of the reduced coupling between the two circuits. The current which can be drawn through a ground on the telephone conductor is likewise less for roadway separations than for the usual joint use separations. Because of these facts, drainage units should not be installed as part of the initial construction. If, after the system is in operation, drainage units are found to be necessary, inductor-capacitor units equivalent to the Western Electric Company's No. 108C unit should be installed.

6.62 Open wire telephone leads which are exposed to single or "vee" phase electric supply circuits operating at 6900-8700 volts to ground will not usually require drainage unless the length of exposure exceeds about 15 miles. Where exposures greater than 15 miles are encountered, an inductor capacitor type drainage unit should be installed at about 8 miles from the beginning of the exposure and at 15-mile intervals. Drainage units should be installed on the two circuits which are subjected to the greatest exposure and should be grounded to a ground rod (Unit PM2 of REA Form 511a).

6.63 Open wire telephone leads requiring drainage, which are exposed to single or "vee" phase electric supply circuits operating 8700-15,000 volts to ground should be equipped with inductor-capacitor type drainage units at 10-mile intervals. The first unit should be installed 5 miles from the beginning of the exposure. Drainage should be provided on the two circuits which are subjected to the greatest exposure and should be grounded to a ground rod as indicated in 6.62.

6.64 If the roadway separation is greater than 35 feet, no drainage units will ordinarily be required.

7. LIGHTNING PROTECTION WIRES FOR POLES

7.1 Lightning protection wires may be necessary to prevent splitting of wood poles in certain areas of high lightning incidence and severe exposures. A study of local conditions should be made by the borrower's

engineer to determine to what extent this protection is required. Normally, extensive use of lightning protection wires should be necessary only in areas having more than 60 lightning storm days per year. In such areas lightning protection wires should be installed on poles which are severely exposed due to being on the top of a hill with little or no shielding such as buildings, trees, or a higher foreign pole line. Protection wires should also be applied to several poles adjacent to hill top exposures. With flat terrain where the exposure is more uniform and less severe, protection wires should be installed on every fourth pole. Pole lightning protection wires are not normally considered necessary in areas which have less than 30 lightning storm days per year. In areas having between 30 and 60 lightning storm days per year application of lightning protection wires to poles at hill top locations should be adequate.

7.2 This form of pole protection normally consists of a wire stapled from the top of the pole to the butt (Unit PM1 of REA Form 511a). Where it is necessary to install lightning protection on an existing pole, a PM2 unit should be used. The PM2 unit consists of a wire stapled from the top of a pole to slightly below the ground line at which point it is connected to a ground rod.

8. GROUNDING NONWORKING OPEN WIRE

8.1 Open wire which is not connected to central office equipment is considered to be "nonworking." Nonworking open wire may have voltages induced in it from nearby power conductors. Voltages may also exist as a result of an accidental contact with the power conductors. All nonworking wire should, therefore, be grounded to a low resistance ground at the beginning of the nonworking section to reduce the effects of foreign voltages. If the nonworking section exceeds 10 miles in length, additional grounds should be placed at approximately 10-mile intervals. The instructions contained in this section apply principally to newly constructed open wire that is not immediately connected for service but apply also to open wire which has become idle because of service disconnection and plant rearrangements.

8.2 When grounded nonworking wire is to be connected for service, do not remove grounding connections until the entire length of nonworking wire has been visually inspected from the ground for contacts with power wires.

8.3 Rubber gloves should be used when making or breaking ground connections.

8.4 Nonworking wire which is required to be grounded should be grounded by one or more of the following methods:

8.41 At cable terminal poles by connecting bridle wire from each nonworking open wire conductor to the cable suspension strand with suitable connectors. The bare ends of the wires of each bridle pair should be twisted together and placed under the washer of the cable lashing clamp.

8.42 At poles equipped with vertical pole ground wires which in turn are interconnected with an MGN, bridle wire should be run from the nonworking wire to the vertical pole ground wire and should be connected to the pole ground wire by means of a split bolt type of connector.

8.43 Grounding may also be achieved by connecting bridle wire from the nonworking conductors to a telephone guy which is interconnected to an MGN. The connection to the guy should be made by means of a strand ground clamp.

APPENDIX A

This appendix discusses in some detail the necessary considerations in determining the placement of power contact protectors, from the standpoint of preventing station fuse holdover.

In order to determine whether a given spacing between power contact protectors will prevent holdover of station fuses in the intervening length of wire, the following considerations are essential.

The conditions most likely to result in holdover are when:

1. A station is connected to a point midway between the power contact protectors;

2. a power contact takes place at this same point;

3. no other stations are connected within this section; and

4. the section is the one nearest to the power system substation feeding the joint use (or crossover) situation.

In order to evaluate the case in question, it is necessary to determine:

1. The impedance of the power circuit from the point of contact with the telephone conductor back to the substation, including the generator (transformer) and ground impedance. Call this Z_p.

2. The expected impedance of the telephone station drop wire (one conductor) and the ground electrode. Call this Z_{st}.

3. The impedance of the telephone conductor (one wire) from the contact point (center of the section) to one of the adjacent power contact protectors including its ground. (MGN ground impedance may be assumed to be 5 ohms.) Call this Z_t.

In the event of a power contact half way between power contact protecto... (worst case) the sequence of events will be:

1. The station protector, being much lower in breakdown than the p.c. protectors will break down first. The power current will be:

$$I_{p1} = \frac{E_p}{Z_p + Z_{st}}$$

APPENDIX A (Cont'd.)

The voltage remaining on the station protector system will be:

$$E_{st1} = I_{p1} Z_{st}$$

2. If $I_{p1} Z_{st}$ is greater than the breakdown of the power contact protector (2000V) one of these protectors will breakdown and the power current will be:

$$I_{p2} = \frac{E_p}{Z_p + (Z_{t1} \oplus Z_{st})}$$

$\oplus$ = Parallel impedance

The voltage remaining on the station protector system will be:

$$E_{st2} = E_p - I_{p2} Z_p$$

If E_{st2} is still greater than 2000V, the other power contact protector will operate and the final power current will be:

$$I_{p3} = \frac{E_p}{Z_p + (Z_{t1} \oplus Z_{t2} \oplus Z_{st})}$$

and the voltage at the station protector will be:

$$E_{st3} = E_p - I_{p3} Z_p$$

If this voltage is greater than 3000 volts the station fuses will holdover, constituting a fire hazard, and the power contact protectors must be placed closer together or the p.c. ground resistance reduced until the station protector potential is brought below 3000 volts.

The following examples illustrate the calculations described above. Assume:

1. Power system of 7200 V to ground.
2. Power system Z to nearest point of contact with telephone line - 10 ohms.

APPENDIX A (Cont'd)

3. Telephone system 109 steel having Z = 8 ohms/k ft.

4. Contact protector spacing 3000 ft.

5. Contact protector ground to MGN = 5 ohms.

6. A telephone station with fuse type protectors connected at the midpoint of the 3000-foot length (worst condition).

7. Power contact at the midpoint as per 6 above.

8. Station ground and drop wire impedance = 15 ohms.

NOTE: 60 Hz impedance and dc resistance are considered equivalent for purposes of these calculations.

The station protector will break down first and the current will be:

$$I = \frac{7200}{10 + 15} = 290 \text{ amps}$$

This current will flow through the station fuses melting the elements and the circuit will become open circuited unless ionization and the voltage available are such as to cause fuse holdover. The second event will be the breakdown of the lower of the two adjacent power contact protectors; the voltage left at this station drop-protector system will be equal to the drop along the telephone conductor to the ground of this p.c. protector.

The voltage across the station drop and protector to ground will be:

$$15 \times 290 = 4350 \text{ volts}$$

This would cause the fuses to holdover, except the rising voltage at the station also appears on both of the p.c. protectors. One of these will break down and the current will be:

$$I = \frac{7200}{10 + (12 + 5) \oplus 15}$$

$$= \frac{7200}{10 + 8} = 400 \text{ amperes}$$

APPENDIX A (Cont'd.)

The voltage across the drop and station protector will then try to rise to:

$$7200 - 400 \times 10 = 3200 \text{ volts.}$$

The holdover capability of the fuses would be exceeded by about 200 volts, except that the rising station voltage also appears across the other p.c. protector and breaks it down.

The current will then be:

$$I = \frac{7200}{10 + (12 + 5) \oplus (12 + 5) \oplus 15}$$

$$= 465 \text{ amperes}$$

and, E across the station drop and protector system

$$= 7200 - 465 \times 10 = 2150 \text{ volts.}$$

The fuses will not holdover and the spacing is satisfactory.

APPENDIX B

This appendix describes procedures which should be followed to determine the spacing of power contact protectors on open wire lines necessary to avoid fusing of the line wire and the possibility of its permanent energization. Coordination between the power and telephone systems is not achieved unless the spacing of power contact protectors is such that the power circuit breakers are caused to lock out on a fault to ground before the telephone wire can fuse open. Burndown of the telephone wire is usually unavoidable.

As an example, assume that a 109-135 steel open wire telephone conductor is involved in joint use with a 7200-volt (phase to neutral) power distribution system. Also, assume that power contact protectors are placed at regular intervals, such as suggested in Table 1 of paragraph 3.213 of this section.

1. For several points along the telephone line, nearest the power supply station, obtain the 60 Hz impedance of the power conductor from the source to possible points of fault to the telephone conductor. Call this Z_p.

2. Calculate the resistance of the telephone conductor from the assumed contact point to the nearest power contact protector. Call this resistance Ro. (This will approximate the 60 Hz impedance.)

3. The resistance of the 109-135 line wire will increase by a ratio of about 8.5 to 1 from a "cold" condition to its melting point of about 1550°C. The average line wire resistance during a contact just failing to fuse the wire will be:

$$\frac{Ro + 8.5\ Ro}{2}$$

and the average fault current will be:

$$I = \frac{7200}{R_g + Z_p + \frac{Ro + 8.5\ Ro}{2}}$$

R_g is the MGN resistance to which the p.c. protector is connected. This may be assumed as 5 ohms.

Referring to Figure 4 find the time in seconds for fusing of the 109-135 wire at current I. If this time is less than the total time required for the power circuit breakers to lock out, there is a good chance that the line wire will fuse open and remain energized indefinitely. Increases of the contact protector spacing may not help this hazardous condition without impairing the protection of the telephone station fuses against holdover. The only recourse under these circumstances is to seek more sensitive circuit breaker settings by the power company.

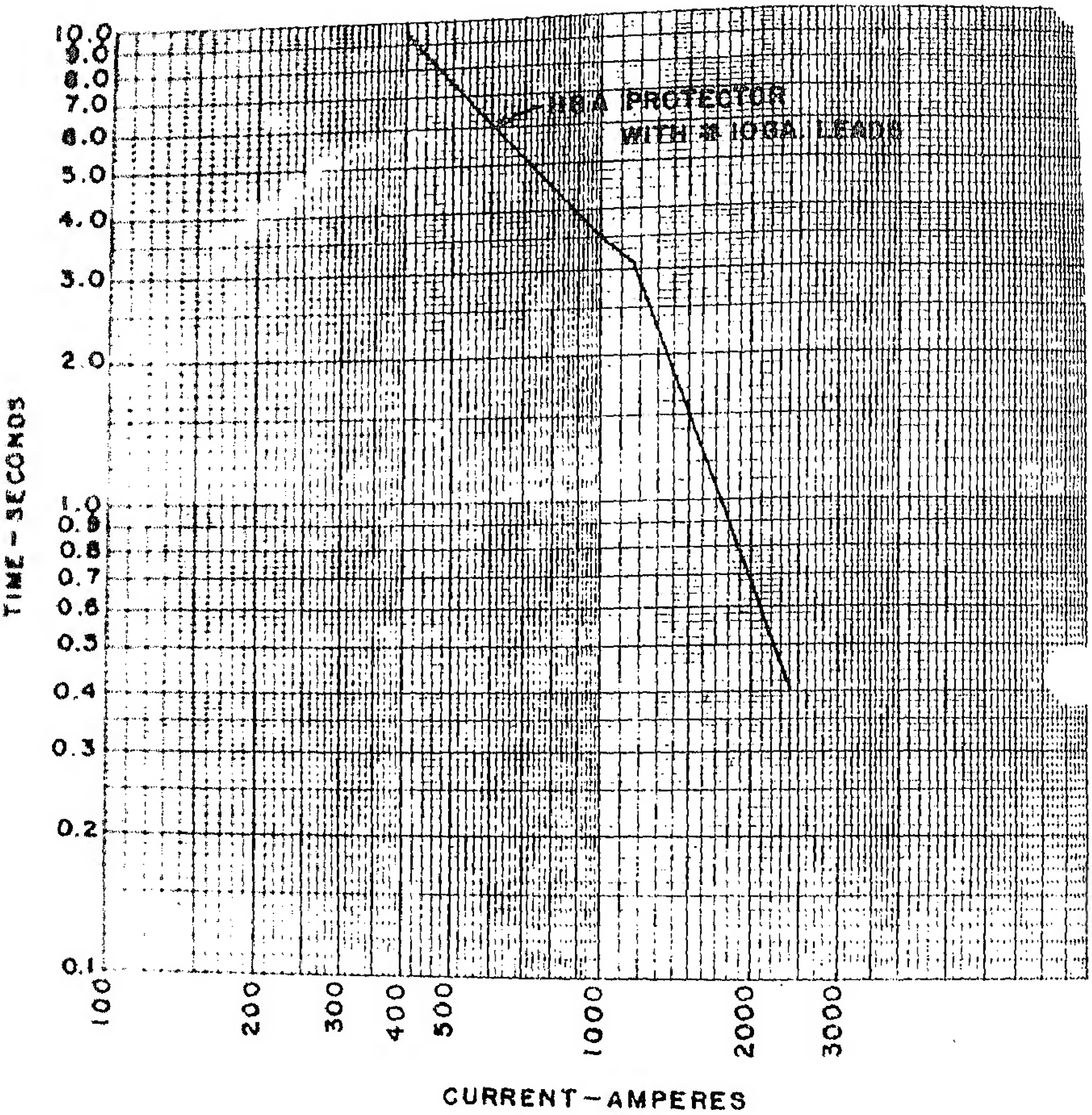
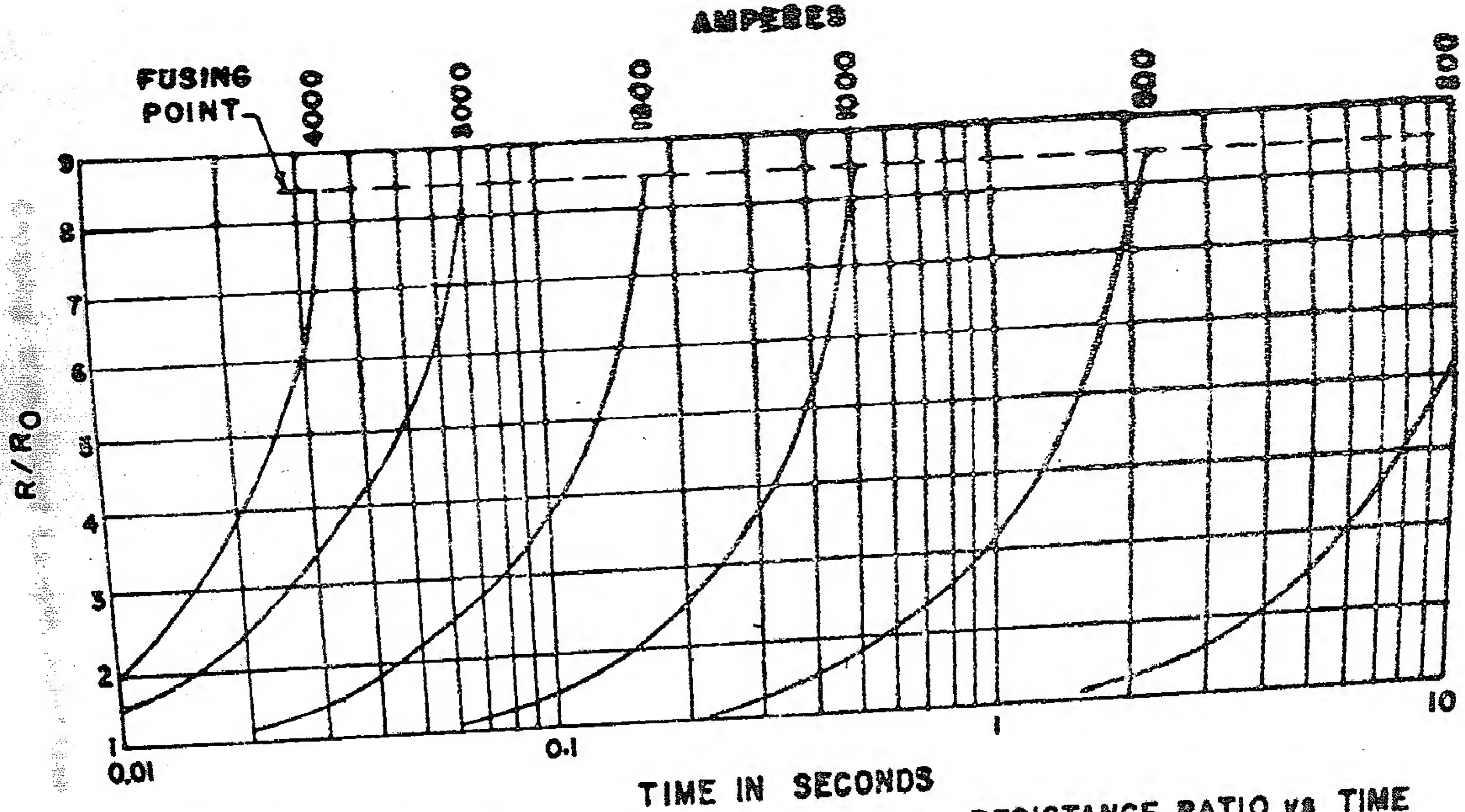


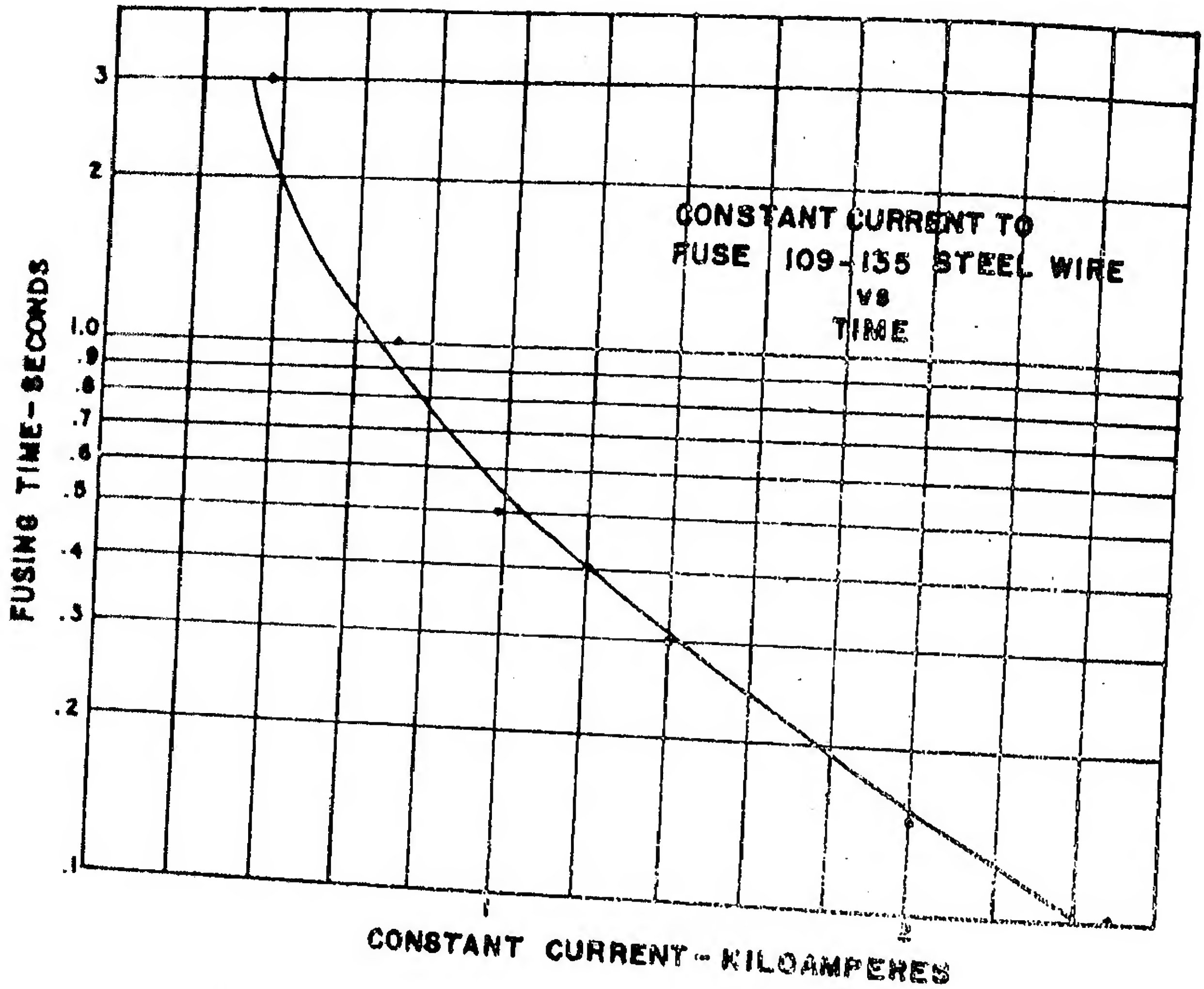
Fig.1 TIME-CURRENT CHARACTERISTIC OF A TYPICAL POWER CONTACT PROTECTOR



R_0 = RESISTANCE AT 20°C
R = FINAL RESISTANCE

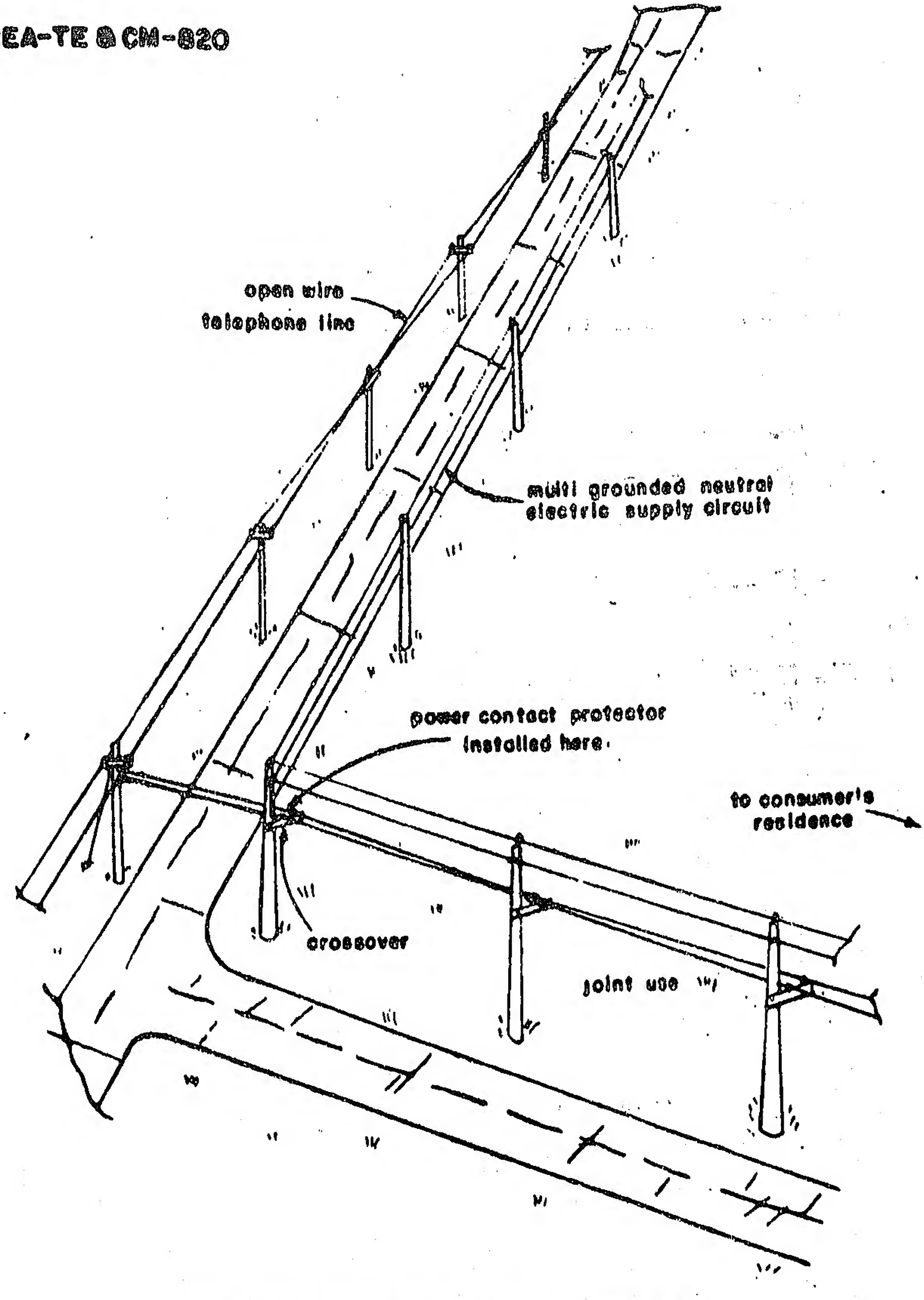
RESISTANCE RATIO vs TIME of 109-135 STEEL WIRE for CONSTANT CURRENTS

Fig. 2



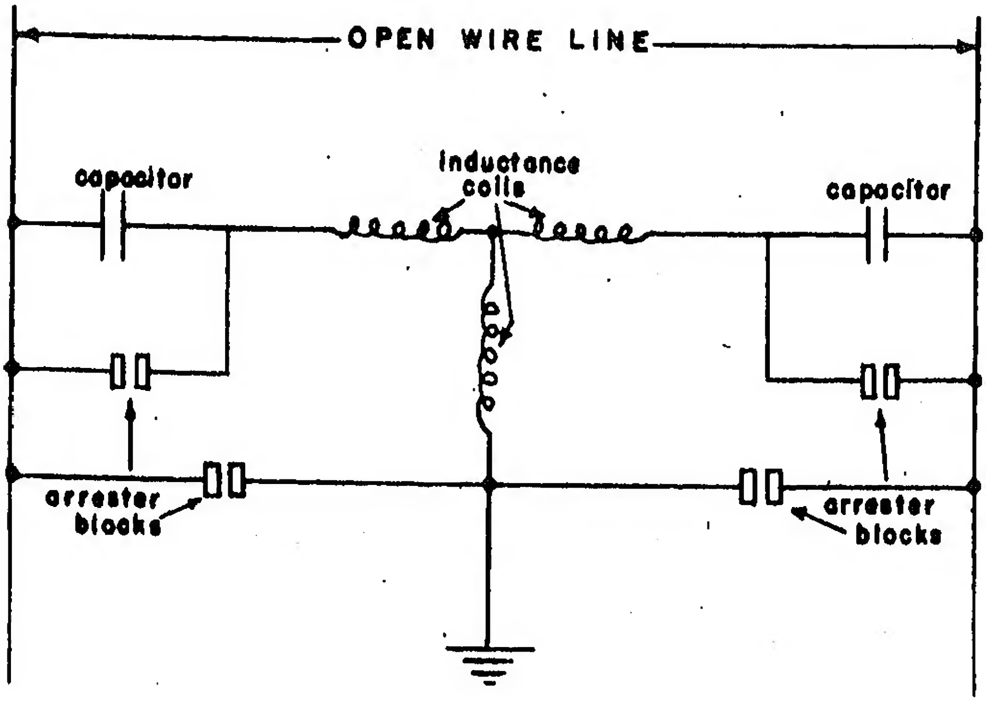
CONSTANT CURRENT TO
FUSE 109-135 STEEL WIRE
VS
TIME
FUSING TIME - SECONDS
3
2
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
1
2
CONSTANT CURRENT - KILOAMPERES

Fig. 3



Crossing With Short Length Joint Use

Figure 4



Typical Tuned Drainage Unit

Figure 5